BIOMOLECULES

Expt. No. .... Date .... Page No. ....

All 'C' comp. we get from living tissues.

* All the elements in sample of earth's crust are also present in sample of living tissue.

Imp NOTE : Relative abundance of → C, H } → higher in (than earth crust sample) sample of living tissue

CHEMICAL ANALYSIS → Take any Living tissue

↓

Grind (using • mortar • pestle) it in Trichloroacetic acid (Cl_3CCOOH)

↓

Obtain a thick slurry

After straining through either → cheesecloth / → cotton

* ((Filtrate)) → ACID SOLUBLE POOL — has → 1000's of organic comp.

* ((Retentate)) → ACID INSOLUBLE POOL

* Analytical techniques $\xrightarrow{\text{give an idea about}}$ • Molecular formula & • probable structure of the comp.

⇒ How do we know about inorganic comps. in a living tissue?

* DESTRUCTIVE EXPERIMENT → ① Weigh a small amt. of living tissue (leaf / liver) } WET WEIGHT

↓

② Dry this tissue

↓

③ Tissue is fully burnt.

← ④ Carbon comps. are OXIDISED to Gas. form: CO_2, Water vapour.

⑤ Remains are called ASH $\xrightarrow{\text{contains}}$ INORGANIC COMPOUNDS → Ca, Mg, Sulphate, Phosphate } seen in ACID SOLUBLE POOL

Teacher's Signature ....

* Order of abundance of element in Human body : O > C > N
  - O → 65%, C → 18.5%, N → 3.3%

* " " " " " " Earth's crust : O > Si
  - O → 46.6%, Si → 27.7%

(AA) AMINO ACIDS

- Organic comp.
- Contains: amino grp and Acidic grp → on same Carbon (α - carbon) → hence called $\boxed{\alpha\text{- amino acids}}$

- Substituted methane → have 4 substituent grps:
  - Hydrogen
  - Carboxyl grp
  - Amino grp
  - Variable grp (R)
    - H → glycine
    - CH_3 → alanine
    - CH_2-OH → serine

* Based on : Nature of R grp $\xrightarrow[\text{are}]{\text{there}}$ many amino acids

★ $\boxed{\text{20 AA} \xrightarrow[\text{in}]{\text{occur}} \text{Protein}}$ = ★

* Chemical / Physical properties of AA are essentially due to → amino grp, carboxyl grp, R functional grp

* If →
  - Amino grp > carboxyl grp → BASIC → Lysine
  - Amino grp = Carboxyl grp → NEUTRAL → Valine
  - Amino grp < Carboxyl grp → ACIDIC → Glutamic acid

* **Aromatic AA** →
  - Tyrosine
  - Phenylalanine
  - Tryptophan

IMP NOTE : Structure of AA (amino acids) changes in soln. of different pH.
↓ bcz of ionizable nature of $-NH_2$ grp, $-COOH$ grp.

ZWITTER IONIC FORM : $\overset{+}{N}H_3 - \underset{}{\overset{R}{\overset{|}{CH}}} - COO^-$

$$H_3\overset{+}{N} - \overset{R}{\overset{|}{CH}} - COOH \rightleftharpoons H_3\overset{+}{N} - \overset{R}{\overset{|}{CH}} - COO^- \rightleftharpoons H_2N - \overset{R}{\overset{|}{CH}} - COO^-$$
(A)

LIPIDS

- Water insoluble
  - Fatty acids
  - Glycerol

① SIMPLE FATTY ACIDS

Fatty acid has carbonyl grp $\xrightarrow[\text{to an}]{\text{attached}}$ R grp $\xrightarrow[\text{be}]{\text{can}}$
- $-CH_3$
- $-C_2H_5$
- Higher no. of $-CH_2$ grp (1 to 19 carbon)

Eg.
- Palmitic acid → 16 Carbon (including 'C' of $-COOH$ grp)
- Arachidonic Acid → 20 carbon (including 'C' of $-COOH$ grp)

FATTY ACIDS can be:
- Saturated — C–C single bonds only
- Unsaturated — C=C, double or triple bonds

② GLYCEROL

- simple lipid
- Trihydroxy propane

* Many fatty acids esterified with Glycerol] depending on no. of fatty acid
  - Monoglyceride — 1 fatty acid, 1 glycerol
  - Diglyceride — 2 fatty acid, 1 glycerol
  - Triglyceride — 3 fatty acid, 1 glycerol

Also called FATS / OILS based on melting point

OILS → lower M.P → hence remain oil in winters
↳ Gingely oil

③ PHOSPHOLIPIDS

→ Eg – LECITHIN

- Lipids having ① phosphorus & ② phosphorylated organic comp.
- found in cell membranes.

grp ★ * Some tissues especially NEURAL TISSUES, have lipids with more complex structure.

Nitrogenous Bases — Heterocyclic rings.

Adenine | Guanine | Cytosine | Uracil | Thymine

* Nitrogenous bases + sugar] → NUCLEOSIDE
* Nitrogenous bases + sugar + phosphate grp] → NUCLEOTIDE

NUCLEOSIDES	NUCLEOTIDES
Adenosine	Adenylic acid
Guanosine	Thymidylic acid
Thymidine	Guanylic acid
Uridine	Uridylic acid
Cytidine	Cytidylic acid

* DNA, RNA] → consists of NUCLEOTIDES only
  → functions as genetic material.

PRIMARY & SECONDARY METABOLITES

PRIMARY METABOLITE

- Present in animal tissues
- Amino acids, sugars
- Have identifiable functions
- Play known roles in normal physiological process.

SECONDARY METABOLITE

- Found in plant cells, fungal cells, Microbial cells
- ★Imp Alkaloids, Flavonoids, Rubber, Essential oils, Antibiotics, Coloured pigments, Scents, Gums, Spices
- Not known, the roles/function of all Sec. metabolites in HOST ORGANISMS.
- Some secondary metabolites have ECOLOGICAL IMPORTANCE

(See table 9·3 Pg. 146)

Expt. No.......................... Page No..........................

BIOMACROMOLECULES

ACID SOLUBLE POOL	ACID INSOLUBLE POOL (contains ① Macromolecules from cytoplasm ② Organelles)
① Mol. wt. ranging from 18-800 Daltons (Da)	① Mol. wt. $\geq$ 10,000 daltons (Da) (except lipids (800 Da))
② These are called MICROMOLECULES or simply BIOMOLECULES	② These are called MACROMOLECULES or Biomacromolecules
③ Represents Cytoplasmic composition	③ POLYMERIC mainly except Lipids → not strictly macromolecules

Q. How do LIPIDS come under acid insoluble pool?

Lipids are arranged in cell membrane & other membranes

When we grind a tissue, we disrupt cell structure & cell membrane are broken into pieces & form Vesicles which are water insoluble hence come under acid insoluble pool.

Eg → PROTEINS, NUCLEIC ACID, POLYSACCHARIDE, LIPIDS } organic comp.

Average Composition of cells → Water > Protein > Nucleic acid > Lipid > Ions

Teacher's Signature.... (W>P>N>C>L>I)

PROTEINS

(Aminoacids 20 types)

→ polypeptides
→ Linear chains of AA linked by – peptide bond.
→ Polymer of amino acid

Imp — HETROPOLYMERS

* Source of Essential amino acids – Dietary proteins

Essential AA	Non Essential AA
• Can't be made by body • Supplied through diet / food.	• Can be synthesized in body

Functions of proteins :
- Transport nutrients across cell membrane
- Fight infectious organism
- Some are hormones, Enzymes

See table 9.5 Pg 147

Imp * Most abundant protein
→ In animal world – Collagen
→ In whole Biosphere – RuBisCo (Ribulose bisphosphate Carboxylase Oxygenase)

POLYSACCHARIDES

→ carbohydrates
→ long chains of sugar
→ THREAD FORM (literally a cotton thread) containing different MONOSACCHARIDES as BUILDING BLOCKS

Cellulose

1. Polymeric polysaccharide
2. Homopolymer of Glucose
3. Does not contain complex helices hence cannot hold I_2.
4. Makes up plant cell walls
5. PAPER made from → PLANT PULP, → COTTON FIBRE is cellulosic

Starch

1. Variant of cellulose
2. Storehouse of energy in plant tissue
3. Blue in colour with I_2 because it can hold I_2 in complex helices
4. Helical Secondary structure

Glycogen

1. Another variant
2. Present in animals

Inulin

1. Polymer of fructose

Lipids, Polysaccharides, Polynucleotides, Polypeptides

Lipids → comes in insoluble fraction but not strictly macromolecule.

Polysaccharides, Polynucleotides, Polypeptides → True macromolecular fraction

Date............

Expt. No.............. Page No..............

* Polysaccharide chain → Right end – Reducing end
→ Left end – Non Reducing end

COMPLEX POLYSACCHARIDES – have building blocks such as
→ Amino sugars → Glucosamine
→ chemically modified sugars → N-acetyl glucosamine

↓ mostly HOMOPOLYMERS

Eg. $\boxed{\text{Chitin}}$ → complex polysaccharide present in exoskeleton of arthropods

NUCLEIC ACIDS

→ polynucleotides

→ Building blocks – $\boxed{\text{NUCLEOTIDE}}$ → 5 types

↓ 3 chemically distinct comp.

- Heterocyclic comps. → Nitrogenous Bases can be
  - substituted purines: Adenine, Guanine
  - substituted pyrimidines: Cytosine, Uracil, Thymine
- Monosaccharide
  - Ribose → nucleic acid having this → $\boxed{\text{RNA}}$ (Ribonucleic acid)
  - 2'-deoxy Ribose → nucleic acid having this → $\boxed{\text{DNA}}$ (Deoxyribonucleic acid)
- Phosphoric acid or phosphate

STRUCTURE OF PROTEINS

→ heteropolymers
→ contain strings of amino acids

- Inorganic – Molecular formula only ($MgCl_2$, $NaCl$)
- Organic – 2-D view (Benzene, Napthalene)
- Biology
  - Physicists → conjure 3-D view
  - Biologists → describe protein structure at FOUR LEVELS

Teacher's Signature..............

Primary Structure

* Positional inform. of protein (which is 1st, which is end).

* Left end → 1st AA → N-terminal Amino acid

  Right end → Last AA → C-terminal amino acid

Secondary Structure

* Protein thread does not exist throughout as extended rigid rod.

it is folded in form of
- Helix (α helix)
- β-Pleated structure

Helix (α helix):

Imp * Only Right handed helices are observed in proteins

Imp * Only some portion of protein arranged in helix

Tertiary Structure

* Long protein chain $\xrightarrow{\text{folded upon itself like}}$ Hollow woolen ball

Imp * 3-D view of protein

Imp * Tertiary structure absolutely necessary for Many Biological activities of proteins

Quaternary Structure

* Assembly of more than one polypeptide or subunits.

* These can be arranged as
  - Linear strings of sphere
  - Spheres arranged in form of
    - cube
    - plate

* Example – Haemoglobin (Hb) $\xrightarrow{\text{has 4 subunits}}$
  - 2 α-type
  - 2 β-type

NATURE OF BOND LINKING MONOMERS IN POLYMER

* In protein – peptide bond $\xrightarrow[\text{when}]{\text{formed}}$ $-NH_2$ of one AA & $-COOH$ of other AA join with elimination of 1 H_2O mol. (DEHYDRATION)

* In Polysaccharides - Glycosidic bond. $\xrightarrow[\text{by}]{\text{formed}}$ DEHYDRATION

* In Nucleic Acid → Phosphate moiety $\xrightarrow{\text{links}}$ 3'-Carbon of one sugar of one nucleotide $\xrightarrow{\text{to}}$ 5'-Carbon of the sugar of succeeding nucleotide

Bond b/w $\boxed{\text{phosphate}}$ & $\boxed{\text{hydroxyl}}$ grp of sugar
↓
ESTER BOND
↓
There is one ester bond on each side hence, Phosphodiester bond.

NUCLEIC ACID $\xrightarrow{\text{exhibit}}$ wide variety of secondary structure.

DNA → Secondary structure → Famous Watson Crick Model.

- DNA is double helix
  ↓
  helical staircase
  ↓
  Each step of ascent represented by a pair of bases.
- Two strands are antiparallel (in opposite dirn)
  5' → 3'
  3' ← 5'
- Backbone is sugar-phosphate-sugar chain.
- Nitrogenous bases projected more or less ⊥ to this backbone but faces inside
- A pairs with T
  G pairs with C
- A = T (2 hydrogen bonds)
  G ≡ C (3 hydrogen bonds)
- Salient features of B-DNA:
  1. At each step of ascent, strand turns 36°.
  2. One full strand, 10 base pairs, total turn 360°
  3. Pitch - 34 Å
  4. Rise per base pair - 3.4 Å

DYNAMIC STATE OF BODY CONSTITUENTS — CONCEPT OF METABOLISM

* Any living organism $\xrightarrow{\text{has}}$ thousands of $\boxed{\text{organic compounds}}$ present in certain concentration [mols/cell or mols/litre]

* One of the greatest discovery → Biomolecules have $\boxed{\text{turn over}}$

means
1) They are constantly being changed into some other biomolecule & also
2) made from some other biomolecules

both the process occur simultaneously in an organism

all the chemical reactions together → $\boxed{\text{METABOLISM}}$

Examples.

1) Amino acids − (minus) CO_2 = Amine
2) Removal of amino group in a nucleotide base.
3) Hydrolysis of a glycosidic bond in disaccride

Imp Majority of these metabolic rxn DO NOT OCCUR in Isolation but are always linked to some other reactions.

'OR' (other words)

Metabolites are converted into each other in a series of linked reactions called {METABOLIC PATHWAYS}

- linear / circular
- criss cross each other (Traffic junctions)
- Flow of metabolites through this pathway has definite rate, definite direction
- This metabolic flow is called → DYNAMIC STATE OF BODY CONSTITUENTS
- Metabolic traffic → very smooth, without single reported mishap

Date.....................

Expt. No.................................... Page No..........................

• Metabolic reactions - Catalysed

Imp

NO uncatalyzed reaction (metabolic) in living system

Imp

* Dissolving CO_2 into water → physical process
→ Catalysed in living system

* Proteins $\xrightarrow[\text{power known as}]{\text{with catalytic}}$ ENZYMES

METABOLIC BASIS FOR LIVING

Metabolic pathways

can lead to

More complex structure ↓ into simpler str.

Example: Glucose $\xrightarrow{10\ steps}$ Lactic acid (in skeletal muscle)

↓

CATABOLIC PATHWAY (constitute degradation)

→ release energy

↓

liberated energy stored in form of chemical bonds in living Organism.

this energy utilised in

- biosynthetic work.
- osmotic work
- Mechanical work

Simpler str. ↓ into Complex str.

↓

Example: Acetic acid ⟶ cholestrol

↓

BIOSYNTHETIC / ANABOLIC PATHWAY

→ consumes energy

(assembly of proteins from AA requires energy)

Imp

Most important form of energy currency in a living system is bond energy in a chemical called ATP (adenosine triphosphate)

Teacher's Signature.....................

Bioenergetics — how cells transform energy often by prod. ATP.

a sub-discipline

THE LIVING STATE

* Blood concentration of GLUCOSE in healthy individual – 4.5 – 5.0 mM
* Conc. of hormones – nanograms / mL

All living organisms exist in a steady-state characterised by conc. of each of these biomolecules → are in a metabolic flux.

* Steady state – non equilibrium state
* At equilibrium – work can't be performed

↓ as living organisms work continuously

* Living state – Non equilibrium, steady state, able to perform work.
* Living process – constant effort to ~~prevent~~ prevent falling into equilibrium.

achieved by → energy input

Hence → 'Living state' & 'Metabolism' are synonymous.

* Without metabolism, no living state.

ENZYMES

1) Almost all enzymes are proteins.
2) Some nucleic acid act like enzymes – RIBOZYMES

* Depict an enzyme by a – LINE DIAGRAM.
* An enzyme (like protein) has a → primary structure ↓ i.e. amino acid sequence of protein

An enzyme has → secondary structure

An enzyme has → Tertiary structure ↓

- Protein chain folds upon itself
- chain crisses itself
- Many crevices / pockets made – Active site

Active site – where → Substrate fits

Active site – through this → enzyme catalyze rxn at a high rate.

Enzyme catalysis	Inorganic Catalysis
Enzymes get damaged at high temp (>40°c)	Work efficient at high → Temp. , Pressure

Exception → enzymes isolated from organisms who normally ~~liver~~ live under extremely high temp → hot vents, Sulphur springs) stable and retain catalytic power even at high temp (80° - 90°c)

Imp → Thermal stability is an important quality of such enzymes isolated from thermophilic organisms.

CHEMICAL REACTIONS

Physical Reactions	Chemical Reactions
1) Change in shape & without breaking of bonds.	1) Bonds broken & new bonds formed during transformation
2) Change in state of matter (ice → water → vapour)	

Inorganic rxn - $Ba(OH)_2 + H_2SO_4 \rightarrow BaSO_4 + 2H_2O$

chemical organic rxn - Hydrolysis of starch.

Rate of physical or chemical process — amount of product formed per unit time.

called VELOCITY if direction of rkn specified.

$$\text{rate} = \frac{\delta P}{\delta t}$$

TEMPERATURE — affects physical & chemical reaction

→ Rate doubles or decreases by half for every 10°c change in either direction.

↓ Catalysed rkn is faster than uncatalysed rkn.

in ~~plasma~~ cytoplasm

$$CO_2 + H_2O \underset{}{\overset{\text{carbonic anhydrase}}{\rightleftharpoons}} H_2CO_3$$

carbonic acid

Presence of this enzyme

1) 600,000 mol being formed every second.
2) Accelerated 10 million times.

Absence of this enzyme

1) Very slow
2) 200 mol. formed in 1 hr.

METABOLIC PATHWAY → 1) Multistep chemical rkn
2) Each step catalysed by $\boxed{\text{same}}$ or $\boxed{\text{different}}$ enzyme complex.

* Glucose $\xrightarrow[\text{10 enzyme}]{\text{10 step}}$ 2 Pyruvic acid

$$C_6H_{12}O_6 + O_2 \longrightarrow 2C_3H_4O_3 + 2H_2O$$

(Remember pyruvic acid ka formula)

* Imp * Metabolic pathway with one or two additional rkns gives rise to variety of metabolic end products.

Skeletal muscle — anaerobic cond. — lactic acid formed
aerobic cond — pyruvic acid formed

Yeast — during fermentation — leads to ethanol (alcohol)

Different conditions — different products possible.

HOW DO ENZYMES BRING ABOUT SUCH HIGH RATES OF CHEMICAL CONVERSIONS ?

- Chemical or metabolic conversion refers to reaction.

Definition of enzymes - proteins with 3-D structure including active site.

$$\underset{\text{substrate}}{S} \longrightarrow \underset{\text{product}}{P}$$

(Enzyme binds to substrate's active site)
↓
cleft or pocket

- Substrate diffuses towards active site.

Read this topic from NCERT full bcz all the lines are very important.

Teacher's Signature............................

Nature of Enzyme Action

form. of this complex important for catalysis

$E + S \rightleftharpoons ES \longrightarrow EP \longrightarrow E + P$

ES:
- highly reactive
- short lived

E → unchanged enzyme

1. Substrate binds to active site of enzyme, fitting into active site.

2. Binding of substrate induces enzyme to alter its shape fitting more tightly around substrate.

3. Active site of enzyme, now in close proximity of substrate breaks the chemical bonds of substrate & new EP complex formed.

4. Enzymes releases products of reaction & the free enzyme ready to bind to another 'S' & run again catalytic cycle.

FACTORS AFFECTING ENZYME ACTIVITY

→ affected by change in conditions which changes tertiary structure of protein.

include
- Temp.
- pH
- change in substrate concentration
- Binding of specific chemicals that regulate its activity

Temperature & pH → Enzymes functions in narrow range of temp & pH

Each enzyme shows highest activity at a particular pH & temp known as (optimum pH & optimum temp.)

↓

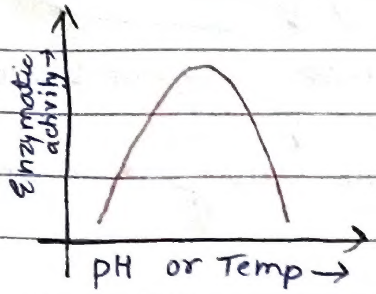
activity declines both above & below optimum value.

Low temp - preserves the enzyme in temporarily inactive state

High temp - destroys enzymatic activity because proteins are denatured by heat.

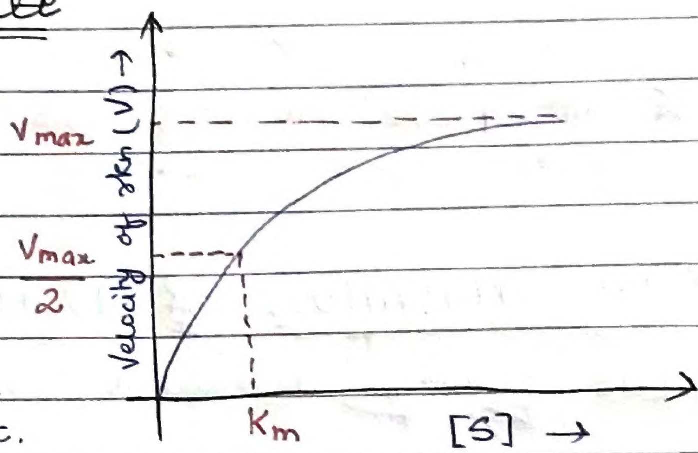
Date.....................

Expt. No.. Page No..



Concentration Of Substrate

Substrate conc ↑↑ , velocity of enzyme rxn rises at first then reaches maxm point which is not exceeded by any further increase in substrate conc.



bcz

enzyme mol. < substrate mol.

& after saturation of these molecules, no free enzyme mol. left to bind with additional substrate molecules.

PRESENCE OF SPECIFIC CHEMICALS

Activity of enzyme $\xrightarrow{\text{sensitive to}}$ presence of specific chemicals that bind to enzyme ⟶ if the binding shuts off enzyme activity

process is called → INHIBITION (chemical called – Inhibitor)

Teacher's Signature..

If inhibitor closely resembles substrate in its molecular structure & inhibits the enzyme activity (Inhibitor & substrate competes for binding site of enzyme) → Competitive Inhibitor

↓

substrate cannot bind

↓

enzyme activity declines

Example

Inhibition of succinate dehydrogenase by malonate

closely resembles in structure

* Competitive Inhibitors are often used in control of bacterial pathogens.

CLASSIFICATION & NOMENCLATURE OF ENZYMES

- 1000s of enzyme discovered, isolated, studied
  - → classified on basis of - type of rxn they catalyse
  - → Divided into → classes - 6 ; → sub-classes - 4-13
  - → named accordingly by a 4 digit number.

OXIDOREDUCTASES/ DEHYDROGENASES

Enzymes catalyse oxidoreduction

S reduced + S' oxidized → S oxidized + S' reduced

TRANSFERASES

Enzymes catalyzing transfer of a group (G) other than hydrogen b/w pair of substrate S & S'.

S - G + S' → S + S' - G

HYDROLASES

Enzymes catalyzing hydrolysis of

- ester
- ether
- peptide
- glycosidic
- P-N
- C - C
- C - halide bonds

LYASES

Enzymes that catalyze removal of groups from substrate by mechanism other than hydrolysis leaving double bond.

$$\underset{|}{X}\ \ \underset{|}{Y}$$
C - C → X - Y + C = C

ISOMERASES

Enzymes catalysing inter-conversion of

optical "

geometric "

positional isomers

LIGASES

Enzyme catalysing linking together of 2 comp.

→ C - O

→ C - S

→ C - N

→ P - O bonds

Date......................

Expt. No....................................... Page No...

CO- FACTORS

Enzymes $\xrightarrow[\text{of}]{\text{composed}}$ one or several polypeptide chain usually
'but'

Sometimes non protein constituent bound to enzyme to make it more catalytically active.
(CO - FACTORS)

Apoenzyme (protein portion) + $\boxed{\text{Co-FACTORS}}$ = Holoenzyme

PROSTHETIC GROUPS

Organic comp.

Tightly bound to apoenzyme

Example

Peroxidase, Catalase → haem is prosthetic grp → part of active site of enzyme

catalyse breakdown of H_2O_2 into $H_2O + O_2$

CO-ENZYMES

Organic comp.

Their association with apoenzyme is transient

occur only during catalysis

Essential chemical component of co-enzymes is VITAMINS

Example -

~~NAD (Nucleotide adenosine~~

~~NADP~~ Coenzyme

NAD (nicotinamide adenine dinucleotide)

NADP (" " " phosphate)

has vitamin niacin

METAL-IONS

They form co-ordination bonds with side chains at active site & at same time form one or more co-ordination bonds with substrate.

Example -

Zinc cofactor of proteolytic enzyme Carbonypeptidase.

* Catalytic activity lost when co-factor removed from enzyme which shows that they play a crucial role.

Teacher's Signature.......................................